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ABSTRACT

Radio Frequency Identification (RFID) enables a contact-free identification of objects either individually or in a bulk mode. The most salient promise of RFID in the realm of logistics is that it reduces object handling costs by automation. However the business potential of RFID reaches well beyond: By providing decision makers with a more detailed, precise, and timely information base, qualitative and indirect benefits can be realized and RFID can be turned into an enabler for far-reaching process transformations. This paper derives a classification framework for RFID benefits that can be used for profiling benefits of envisioned RFID initiatives. The profiles are designed to support a targeted selection of benefit measurement approaches as well as for an identification of relevant gaps in the exploitation of the technology. Two complementary case studies are introduced and discussed to illustrate how resulting benefit profiles can be utilized.

Keywords

RFID, qualitative and indirect benefits, decision support, logistics, supply chain management

RELEVANCE

There is hardly an information technology which has attracted more attention in recent years than Radio Frequency Identification (RFID) – the collection of identification data from physical objects based on radio transmission. RFID systems enable a contact-free bulk identification of objects on pallet, box, or even item granularity (Angeles, 2005; Asif and Mandviwalla, 2005; Lahiri, 2006).

In the realm of logistics, RFID promises to unlock significant business value by automating data collection and by enabling new products and processes (Agarwal, 2001; Kambil and Brooks, 2002; Kinsella, 2005; Wong, McFarlane, Ahmad Zaharudin and Agarwal, 2002). A current driver for RFID applications in supply chain environments stems from the standardization activities carried out by the EPCglobal consortium. The EPC standards cover characteristics of RFID hardware, the structure of the stored data, and the middleware for data exchange across corporate borders (Angeles, 2005; EPCglobal, 2007b; Lahiri, 2006).

Next to increasing cost efficiency based on more economical handling procedures for logistical items (Knebel, Leimeister and Krcmar, 2007; Lieb and Bentz, 2004), an important value impact is also assumed to come from indirect and qualitative changes (Lee, Cheng and Leung, 2004; Wong et al., 2002; Faupel, Strüker and Gille, 2008; Gille and Strüker, 2008) like an enhanced transparency or a better decision support.

As will be discussed, different RFID applications come with different profiles of benefits that need to be handled differently during evaluation – some focus on more infrastructural and qualitative changes while others are primarily aimed at local automation with immediate monetary consequences. This paper proposes an approach to act accordingly: A classification tree for benefits evaluation is derived that is designed to be the bases for a profiling of benefits. The resulting profiles are not only designed to choose a pertinent mix of valuation metrics and methods but also to identify gaps in the exploitation of the technology. The application and the relevance of the approach are exemplified with two complementary cases.

BENEFITS OF RFID

RFID technology is supposed to foster a higher precision and a higher frequency of object identification and an reduction of errors (Tellkamp, 2006). Taken together, RFID should lead to a better information base and in turn to a more effective support for decision makers. Combined with information infrastructures like the EPCglobal based information exchange infrastructure “EPCIS” (EPCglobal, 2007a) this can entail far reaching *indirect and qualitative* effects on the supply chain, that need prudent appreciation.

There already is a relatively large body of studies that cover benefits associated with RFID. In general four types of approaches to their systematization can be distinguished:

A “**collecting and grouping”** approach, in which case study or desk research results are compiled and grouped to general, disjoint classes. Respective publications often provide rich insight into the spectrum of potential RFID applications. Examples encompass (Agarwal, 2001) who distinguishes between “supply chain agility”, “revenue generation” and “cost reduction”.

A “**locus of impact**” approach, that highlights where in the chain and/or for whom benefits arise. A process level approach can be found at (Morán, Ayub and McFarlane, 2004) who sort effects based on the affected sub-processes. (Zaharudin, Wong, Agarwal, McFarlane, Koh and Kang, 2002) distribute benefits to supply chain partners.

An “**indicator system**” approach that adapts established evaluation systems to RFID implementation, e.g. by applying a value based management scheme and assigning benefits to the respective categories. Examples include (Alexander, Birkhofe, Gramling, Kleinberger, Leng, Moogimane and Woods, 2002) or (Fleisch, Ringbeck, Stroh, Plenge and Strassner, 2005) who build their benefit systematization upon a value driver tree. An alternative that is currently pursued is a mapping of RFID benefits to a Balanced Scorecard. The advantage of such classifications lies in its gain in systematization and the coherent structure that can be translated into governance structures.

A “**layer of impact**” approach that distinguishes benefits based on the granularity layer on which the respective effects surface. An example for this is (Bovenschulte, Gabriel, Gaßner and Seidel, 2007), who differentiate between long term, mid term, and short term effects. The (METROGroup, 2004) separates between automation benefits, new process-enabling benefits (local), serialization benefits (visibility across enterprise borders), and collaborative benefits.

As one of the goals of the presented research aims at selecting valuation instruments, the fourth approach provides the best vantage point: Which each type the scope of the RFID application widens and thereby more intervening factors and uncertainties need to be taken into account while evaluating the resulting benefits:

The smallest changes occur if pure **automation effects** are addressed, i.e. when manual data collection is replaced with automatic measurements. An example is an automation of sorting procedures (Boushka, Ginsburg, Haberstroh, Haffey, Richard and Tobolski, 2002).

If one takes the results of an RFID data collection into consideration, effects on process level become apparent: RFID increases the quality of the available information base for decisions. These **informational effects** do not require modified structures and processes. They might, however, include additional data gathering which is not economical feasible without RFID. An example is an enhanced visibility of assets during transportation and delivery (Boushka et al., 2002).

Further than the named layers reach structural changes in *existing* processes which are enabled by the enhanced information base. These **transformational effects on process level** require the purposeful redesign of information and good flows as well as of responsibilities, e.g. by shifting decision rights towards a central hub in the supply chain (cf. 4.2). The highest degree of variation go along with **transformational effects on firm level** which subsume crafting new products, delivering a new set of services to customers, addressing new markets, and the like.

This classification especially allows for a first grouping of impacts based on project properties. It has been used as an initial grid to compile a list of benefit categories with the aim to systematically recognize, exploit, and eventually measure the full potential of the technology. However, in the course of this effort, it turned out that the above mentioned categories alone are still too broad to meet those objectives – the effects in each category are heterogeneous regarding the measurability of the indicators, the relevant comparison baseline, and the necessity of supporting organizational and technical measures (e.g. systems integration, organizational harmonization, etc.). Therefore, the following section fans the classification further out to come to a more precise instrument.

A FRAMEWORK FOR PROFILING RFID BENEFITS

A valid evaluation of RFID benefits needs to recognize the impact of the technology on informational, and transformational level. This entails the need to become aware of both *indirect and qualitative* effects, to be able to separate *RFID-induced* benefits from effects resulting from *enhanced information logistics and standardization*, and to also include benefits on *managerial decision support.* As will be shown, albeit some overlapping between the classifications does occur, the distinctions cannot be used interchangeably. They much rather span a tree of possible benefit types that can result from RFID technology.

Direct and Indirect Benefits

The most prominent effect of RFID is that it facilitates data collection up to the point of a full automation. Alexander et al. (Alexander, Gilliam, Gramling, Kindy, Moogimane, Schultz and Woods, 2002) present various examples for an RFID based reduction of object identification activities – including the avoidance of repeated measurements to cope with erroneous results. As there is a direct base for comparison, such effects can for the most part be easily translated into either a tangible monetary value (cost savings) or into an increase of quantifiable performance indicator values like "number of wrong deliveries", "damaged items", etc.

However, the identification and evaluation of a more precise, more accurate, and/or a more frequent data collection that is utilized beyond the immediate locus of the data collection is harder to tackle: Those effects are not generating value by themselves. They much rather require a purposeful application of the data to unlock business potential. The value of the respective effects is thereby *indirect* in nature.

In this paper **indirect benefits** of RFID are understood to be value-generating effects resulting from the purposeful distribution and utilization of RFID data.

Monetary and Qualitative Benefits

While most of the direct and some of the indirect benefits are monetary, e.g. reduced storage costs due to more commensurate replenishment processes (Mueller and Tinnefeld, 2007), others are primarily altering the *quality* of the processes or their outcomes, i.e. they enhance effectiveness rather then just efficiency. Examples encompass a reduction of mistakes during materials handling (Boushka et al., 2002). These *qualitative benefits* introduce another level of indirection between the application of RFID and monetary consequences.

For the following sections **qualitative benefits** of RFID are defined to be value-generating effects resulting from positive qualitative changes of the process outcomes enabled by RFID technology.

For benefit evaluation this differentiation is imperative as the evaluation of qualitative benefits usually requires the projection onto a application-specific set of non-monetary performance indicators like cycle times or service levels. Common indicator sets like the ones in the SCOR model (Kasi, 2005; Supply-Chain-Council, 2006) provide a valuable source for the selection of such indicators.

It needs to be considered that the implementation of an RFID application often entails both qualitative and monetary benefits at the same time, e.g. in joint forecasting (Aviv, 2002; Huang, Lau and Mak, 2003): In joint forecasting scenarios, RFID technology presents an option to collect and store high-resolution information on stock levels and good flows over time (Lapide, 2004). Monetary value results from a more directed stock keeping that goes along with reduced cases of economical obsolescence. This is mirrored on the qualitative side as an increased fit of the products in store with customers' demands.

Innate and Collateral Benefits

Unlike automation effects, indirect and qualitative effects can often not be fully associated with RFID as they also rely on changes in systems, processes and structures. To come to a fair evaluation of RFID technology, it needs to be scrutinized whether the resulting benefits are indeed enabled by RFID or whether they are solely based on overall general system changes that would not require RFID.

However, a major driver of many current RFID implementations is the availability of the EPC standards for the tags, the readers, the data format, the middleware, and for the systems that allow an exchange of RFID data. The EPC-code comes as a natural primary key that fosters data sharing among organizational units and across enterprise borders and the EPCglobal network facilitates their transfer.

Benefits that are merely resulting from a standardization of codes or systems are here considered to be **collateral benefits** that cannot be excluded from a RFID evaluation. The higher cost-efficiency, precision, quality, and frequency of data gathering on the other hand are **innate benefits** of the technology.

Both types of effects respectively need appreciation. A thorough differentiation is crucial, though, as the evaluation of collateral benefits requires another baseline for comparison: subject to the valuation of collateral benefits is the EPC infrastructure and no longer the actual identification technology. The baseline for comparison are not distinct identification alternatives but rather established approaches to data sharing, e.g. based on EDI or on exchange formats like XBRL.

Moreover, infrastructural changes have both qualitative and monetary effects and are often a prerequisite for a number of additional measures. Such "platform creation" settings are therefore prone to be tackled with more sophisticated evaluation methods like variants of the real options approach (Copeland and Antikarov, 2001; Trigeorgis, 1996).

Operational and Managerial Support

The usage of RFID data is by no means limited to operational support. It can also act as the foundation for more far-reaching management decisions, especially if data is integrated, aggregated, and put in its historical context. Examples include an analysis of supplier performance or tackling the root causes for a repeated spoilage of perishable goods. Respective decision support is usually discussed in the context of "Management Support" or "Business Intelligence" and associated with the use of integrated, harmonized and aggregated data (Baars, Kemper, Lasi et al., 2007).

In this paper **managerial support benefits** denote effects stemming from an enhanced management support with integrated, aggregated, and usually further refined RFID data.

For this framework benefits are exclusively attributed to the "managerial support" category, if and only if they result from collected RFID data. On the other hand, "ex-ante" changes introduced to operational processes in the course of an RFID implementation are subsumed under "operational support", although those changes of course very well require management decisions.

Managerial support not only calls for different systems, concepts and methods but also for different approaches to benefits evaluation: Because managerial decisions lead to changes of products, services, and processes, the resulting benefits are in general less tangible than in a pure operational environment where decisions are framed by predetermined processes and structures.

Managerial benefits are indirect by nature as they rely on information usage. Besides, the role of collateral RFID benefits is bigger in managerial applications because data exchange, integration, and harmonization are core pillars of reasonable management support and respective standards foster those. However, these effects can be classified as "innate" if they rely on a detailed resolution of the data for cause detection, e.g. to find the causes of spoilage with sensor-enhanded RFID tags.

Furthermore one needs to be aware that each data collection on operational level might be used for managerial decisions later – if the historical data is kept and stored in an adequate manner.

Interplay with the Layers of Impact and the resulting tree

Effects on **automation layer** result from an injection of technology into existing processes and structures and are thus direct and by definition innate. The effects are moreover monetary as the process output is not immediately touched. The benefits on this layer can therefore be directly captured, e.g. with simple Time-Savings-Time-Salary calculations (Sassone and Schwartz, 1986) or by applying Activity Based Costing approaches (Kaplan and Cooper, 1998).

Informational layer effects primarily rest on an enhanced information base. This encompasses both direct and indirect effects. The error reductions and an avoidance of correction activities are direct according to the definition given above, while enhanced replenishment processes are indirect. Some of the benefits are immediately monetary, e.g. when recall processes can be limited to affected units only and thus curb recall costs as stated in (METROGroup, 2004), while others are more qualitative in nature, for example a reduction of customer complaints.

When crossing enterprise borders, information layer effects are often at least partly collateral, e.g. when considering the avoidance of an "bullwhip effect" (Mueller and Tinnefeld, 2007; Simchi-Levi, Kaminsky and Simchi-Levi, 2003).

Furthermore they subsume both operational and managerial effects: As long as managerial decisions do not lead to lasting changes they are not considered transformational in this framework. Managerial effects on information layer especially address management-support backed exception handling scenarios (Grigori, Casati, Dayal and Shan, 2001) that need precise insight into historical process data for a purposeful "slicing" of multi dimensional data collections. Scenarios include the reaction to an unexpected closing of transportation routes (Cheung and Muralidharan, 1999) under consideration of aggregated indicators gathered over time. A RFID-based inventory tracking can provide a deep socket of information for such situations.

Transformational layer effects also subsume all discussed types of indirect effects: monetary and qualitative, innate and collateral, operational and managerial.

It strikes that indirect transformational effects based on an enhanced *managerial support* are at best hinted at in current publications, although a wealth of possible scenarios can be derived from informational layer: The identification of patterns within existing processes can be the starting point for imposing sustaining changes. The problem with ex-post reorganizations is that they are particularly hard to predict. They need to be tackled by estimating and valuating a corridor of reasonable scenarios.

Figure 1 visualizes the resulting classification tree that is also the bases for the benefit profiling as well as examples. Note that the sequence of the rows and columns is **not** meant to represent the relative importance of the effects. The order is much rather chosen to support visualization: More direct benefits come at the top whereas far reaching and indirect effects are placed at the bottom. Regarding the categories, rather project and business driven categorizations are shifted to the left while those which are closer related to infrastructures and systems can be found on the right hand side.

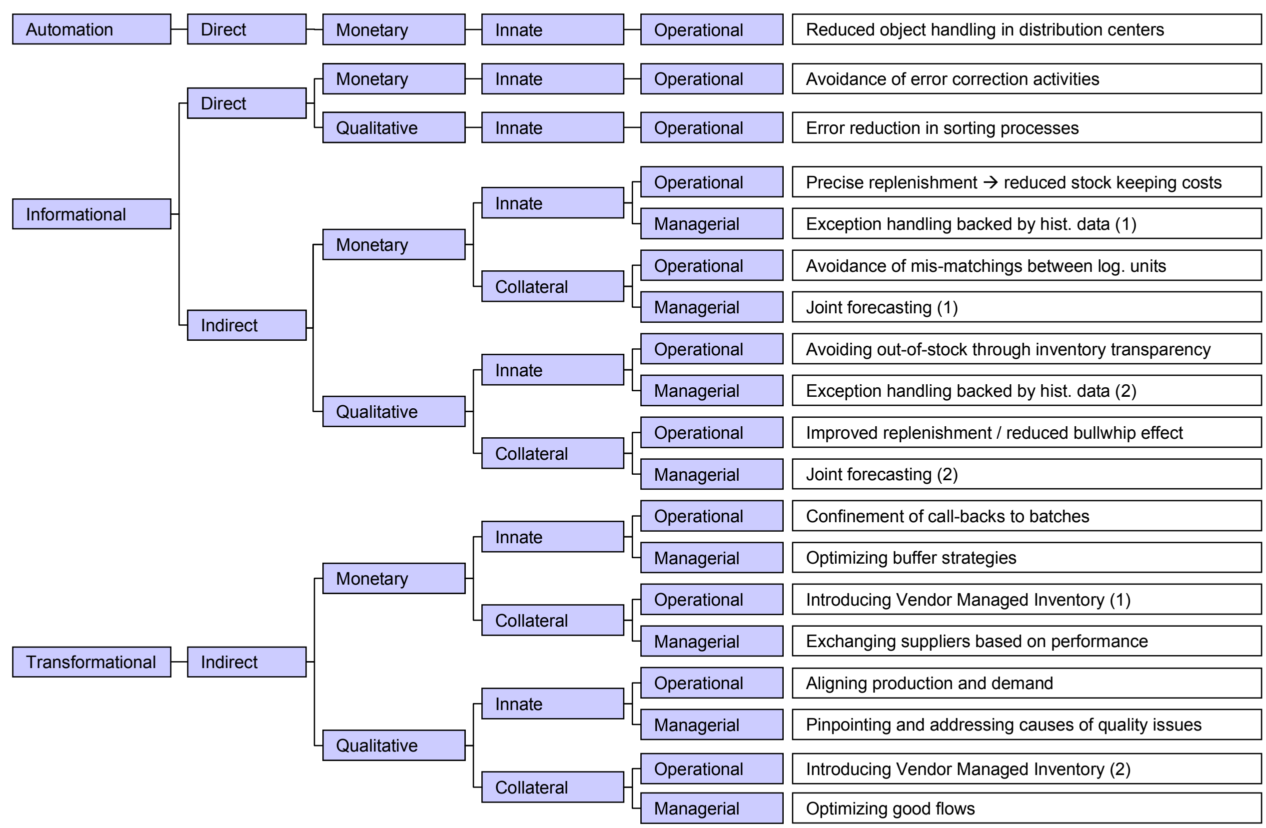

Figure 1: Classification of RFID Benefits – RFID profiling framework

CASE STUDIES

The two cases used for the discussion of the profiling framework are part of an ongoing research project on the benefits of RFID. The first case pertains to a global RFID initiative of a leading European retailing group, while the second is derived from a series of interviews with manufacturers in the food sectors who are suppliers of the before mentioned retailer. The cases are thereby complementary and reflect two views on the diffusion of RFID technology and RFID standards. Both studies encompassed an elicitation of processes and pursued RFID applications, and a discussion of potential benefits. The resulting effects have afterwards been mirrored against the proposed framework.

Case 1: EPCIS and RFID as a bases for a reorganization of a retail supply chain

The first case was accomplished within the logistics project of a European retailing group that especially addressed coupling EPCIS infrastructures with systems for management support (active data warehousing and analytical systems), as this was seen as highly relevant within the project consortium. Applied methods were document analysis, observation, workshops, and narrative interviews. The derived scenarios reflect the actual business demands, the envisioned applications, required data, and possible benefits of the concrete analyses.

The chain in discussion includes Chinese manufacturers, a consolidator located in China (responsible for the bundling and the shipment of goods from different suppliers in containers), a Goods Distribution Centre (GDC) in Germany (handles the goods transfer to the individual retailers), as well as retail outlets across Europe. In the given case, the involved retailing group is the driving force behind the introduction of RFID.

Assumptions being made for the derived scenarios were the implementation of EPCIS alongside the introduction of Vendor Managed Inventory, and a far reaching redistribution of decision rights to the GDC which is turned into the core decision unit in the chain for all types of distribution related activities. For some scenarios, an successful application of RFID tags on item level and/or the coupled use of RFID tags and sensors was assumed. The conceived infrastructure is depicted in Figure 2.

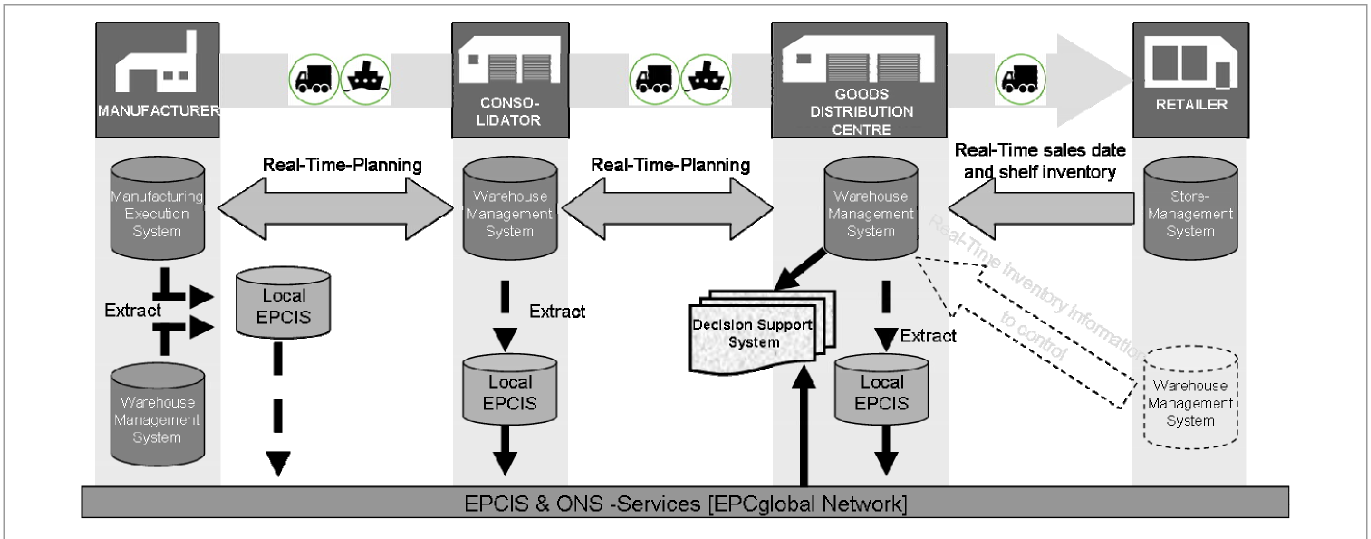

Figure 2: Concept of the decentralized Data Management in the Supply Chain

Based on these presumptions, data collection points were derived and discussed for each type of partner in the chain. Furthermore the availability of additional data sources was elicited. Eventually scenarios for RFID data usage including their respective data demand were derived. All scenarios need to be classified as "transformational" as they rely on a major restructuring of the delivery process.

- *Maximization of shelf space utilization*
  In the first scenario the GDC distributes goods to retailers under consideration of the amount of goods in the shelves and thereby aims at a maximization of shelf space utilization. The scenario makes use on the possibility to capture availability data in real time and on item level and is thereby innate. Furthermore the effects are indirect and primarily monetary. Although being operational, ex-post managerial analysis allows for calibrations.
- *Relocation of goods between retailers*
  In this scenario the GDC is responsible for balancing out shortages by directing good transfers among different retailers. The effects in this scenario are primarily qualitative in nature (avoiding out of stock situations). They are at least partly collateral as the pivotal enabler is the data transformation and integration infrastructure.
- *Selective call-back of articles and refilling the shelves*
  In the third scenario call back activities are handled selectively, i.e. only affected batches will be taken out of the chain.

This makes a highly precise data collection necessary and is an innate effect with obvious monetary and qualitative consequences.

- *Identification of root causes for defective articles*
  The next scenario aims at identifying root causes for quality issues. This requires RFID on item level, tracking and tracing data, as well as sensor information – in an integrated fashion. The resulting qualitative and monetary benefits are therefore both managerial and innate.
- *Demand driven order process*
  The fifth scenario aims at a more demand driven order process which goes along with reduced lot sizes and a higher order frequency – coordinated by the GDC and based on real time RFID data. The scenario is for a large part operational and collateral. It has positive qualitative effects on order fulfillment, lead times and delivery performance but comes at the price of enhanced transportation costs.
- *Prioritization of deliveries and goods distribution under constraints*
  Here the shipment at the consolidator is prioritized by the GDC according to the current demand data and loaded to containers on the bases of additional data like weight, size, and risk of damage. Again, this scenario is only partly innate and operational in nature.
- *Alternative transport possibilities*
  The last analysis pertains to route planning. In the given case, RFID, GPS, and sensor data enable the GDC to (almost) constantly monitor the status and the location of moved goods and to be able to intervene as soon as possible and with a large information base. This is an example for exception handling based on better managerial support. It is primarily collateral.

Figure 3 shows the derived benefit profile:

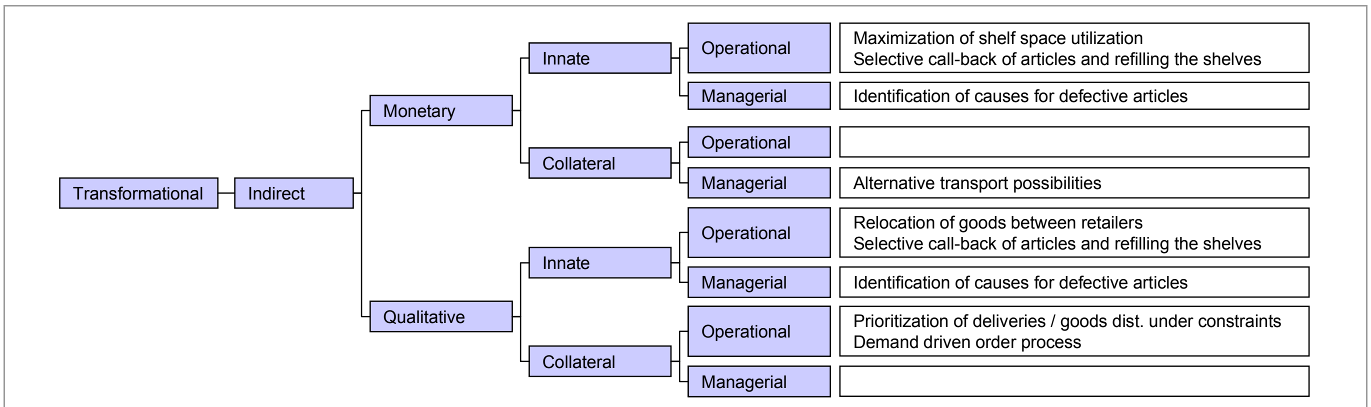

Figure 3: Classification of the RFID impacts for case 1

Naturally, the results blend out pure informational and automation effects as this was not subject to the given case study. It is understood that these types of benefits are scrutinized within the retailer's project as well. On the other hand, the case study shows that the retailer is well aware of far reaching transformational effects and actively drives its partners toward realizing them. Also this case sheds the light on the importance of collateral effects as data exchange is at the core of the project.

A benefits evaluation for this case needs to consider the intricate interrelations between the realization of the assumptions and the different, indirect and often qualitative effects. It might be built upon a real option approach, in which the different scenarios are treated as options for future actions. Each of the separate scenarios needs its own appraisal, e.g. by applying a scenario and probability based method.

Case 2: RFID in production logistics

The second case was taken from an (ongoing) series of interviews with manufacturers of food articles that are expecting to be *forced* by a retailer to add RFID tags to their products mid term and therefore evaluate how to gather benefits from this.

Until now the manufacturer in discussion concentrated its evaluation of RFID on applications along production logistics processes. The basic process is currently structured as follows:

Raw materials (vegetables etc.) and packaging materials (glasses, boxes and the like) are received by the goods receipt, where quality and quantity are controlled based on the respective order information. Depending on the inventory status, the materials are either directly transported to production, or stocked. Because of the perishable nature of the grocery materials, the inventory time is limited to 2-3 days. During the production process, additional information (quantity, time, temperature, etc.) for both raw materials and semi-finished materials is collected for production control. At the time the goods are issued, product information will be delivered to the trading partners based on bar code electronic format (EAN 128 Code).

Within this setting, the following scenarios were deemed interesting:

- Automatic goods receipt and adjustment of order information
- Simplified goods packaging processes
- Contact-free documentation of transport information
- Enhancing inventory visibility to reduce inventory levels
- Permanent stocktaking for packaging materials to adjust order sizes
- Enhanced and easier traceability of packaging materials for locating damages or losses

All associated benefits are either on automation or informational level, and with one exception all address monetary benefits that can be calculated in a relatively straightforward manner. The considered benefits profile is depicted in Figure 4.

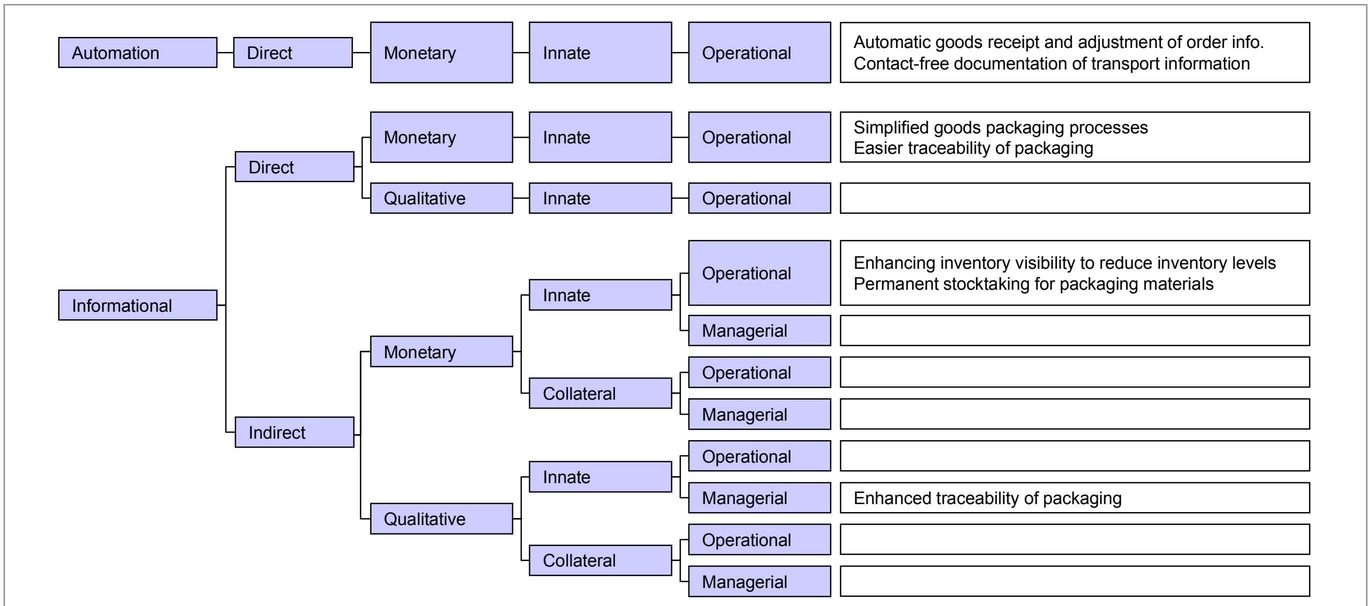

Figure 4: Classification of the RFID impacts for case 2

The retailer has so far deferred an implementation, because the cost-benefit ratio was not yet clear –based on the above scenarios. It is striking though, that vast areas of the tree stay unfilled. As the manufacturer will have to apply the technology in the mid term anyway, applications beyond local automation should at least be evaluated – especially the application of managerial applications. Whether this and/or the utilization of data exchange via the EPCIS network is possible and recommendable (e.g. by identifying causes of damage or customer preferences) is subject to ongoing research.

CONCLUSION AND DISCUSSION

The presented framework is understood to be the first milestone in the development of a further reaching concept for a systematic elicitation and evaluation of RFID in the supply chain. The next necessary steps include the attachment and adaptation of concrete metrics and valuation methods to the various benefit types.

This paper focused on the benefit side only. It is understood, that cost structures need to be included in a complete business model for RFID and the elicitation of the cost side goes along with several severe challenges as well. Moreover, the profiling will be applied on more cases and with higher level of detail.

Regarding possible conclusions after applying the framework, one has to prudently consider issues of data ownership and acceptance as well. In the retail case, this was facilitated by the buying power of the involved retail group. If an enhanced data sharing is an option for the manufacturer, needs to be evaluated.

Further research aims at evaluating the business potential on managerial level and its relevance for various partners in the supply chain. This encompasses the development and validation of prototypes that exemplify the potential and limitations.

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